Analysis of surface temperature dynamics of switching vacuum arc contacts

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FROM IDEA TO PROTOTYPE

Introduction

Motivation

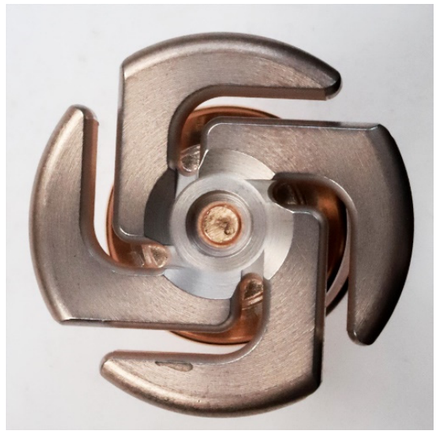
- Vacuum interrupters possess outstanding insulation properties, have simple design, provide environmentally friendly operation – zero emission (no harmful gases, no light emission, no waste products), are maintenance-free
- High-current operation is characterized by strong electrode melting and evaporation and requires measures for reduction of thermal load
- Two basic operation principles uses magnetic field for arc control:
  - radial magnetic field (RMF) contacts provide arc rotation over the electrode surface (constricted arc)
  - axial magnetic field contacts (AMF) cause an expansion of the arc column over the total electrode surface (diffuse arc)

Subject

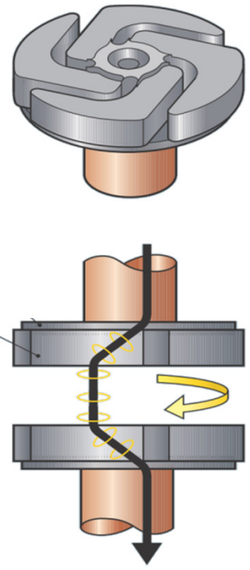
- Study of applicability of optical methods for surface temperature determination of switching contacts with various geometry

Studied electrode systems

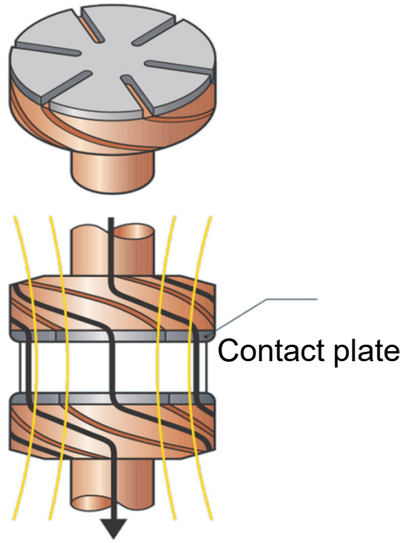
Radial magnetic field contact (RMF)

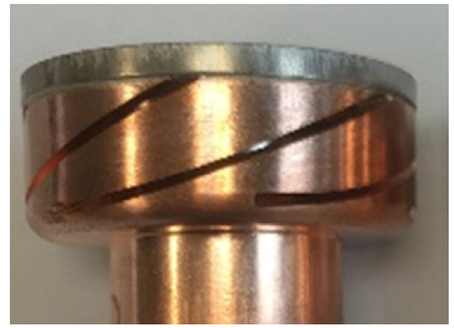


CuCr alloy, ∅34 mm

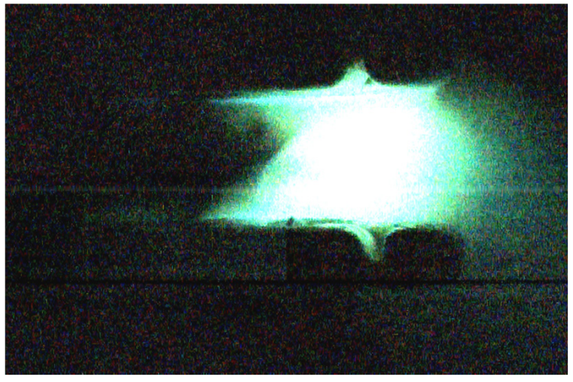


Axial magnetic field contact (AMF)





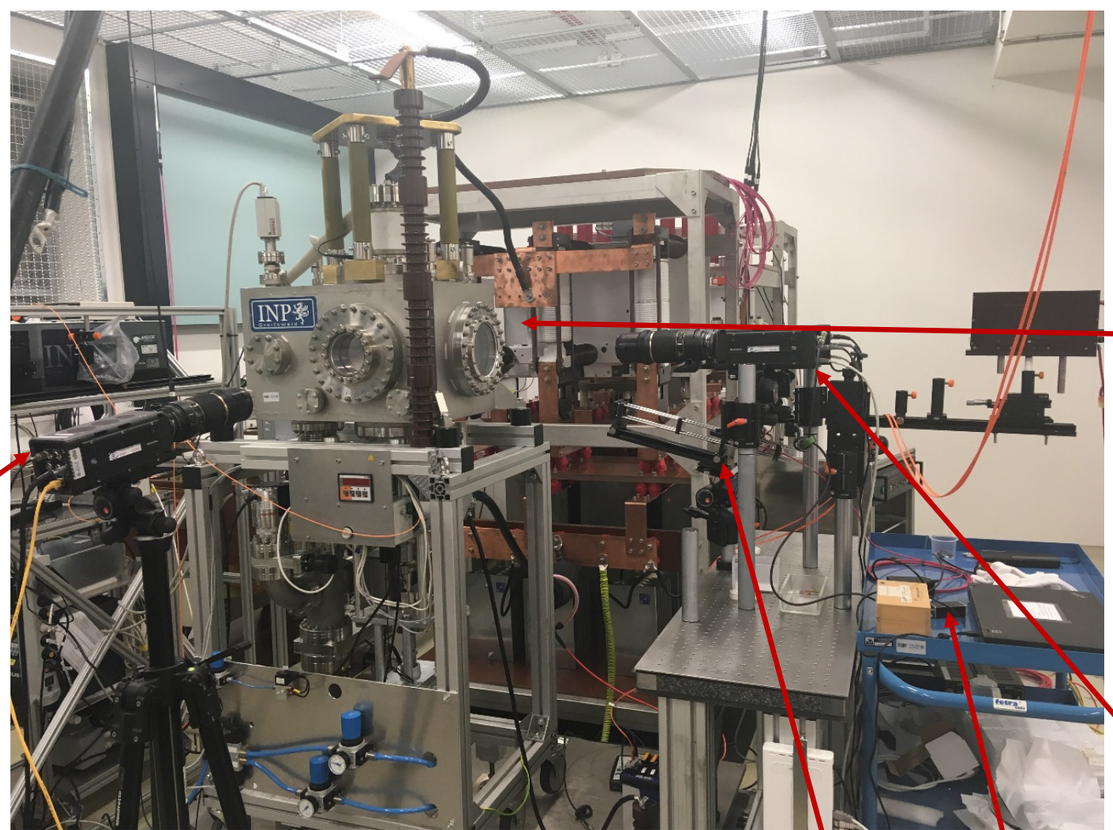
CuCr alloy, ∅38 mm

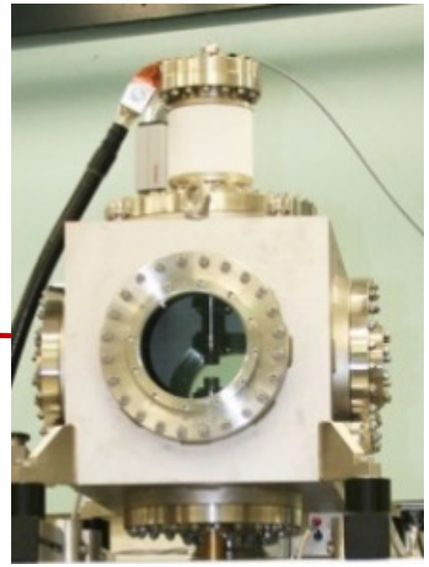


Rotation of a constricted arc

Diffuse arcing

Experimental setup





vacuum chamber with moveable electrodes

High-speed camera, arc dynamics

high-speed cameras with filter, surface temperature

NIR optics

NIR spectrometer

- Use of optical diagnostics: non-invasive methods, quantitative characterization of electrode surface

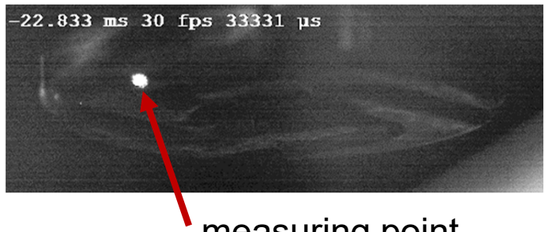
Methods: I NIR spectrometry

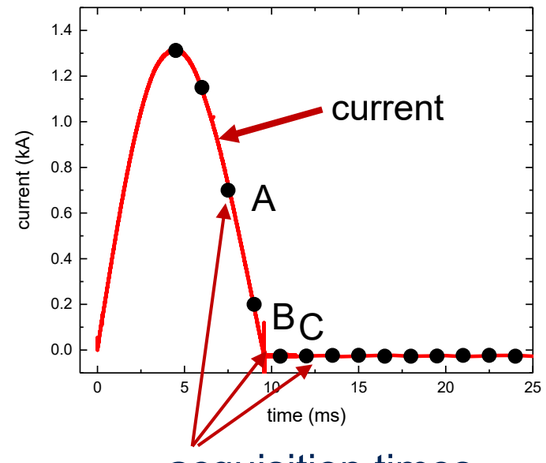
NIR spectrometer
900-1600 nm

+

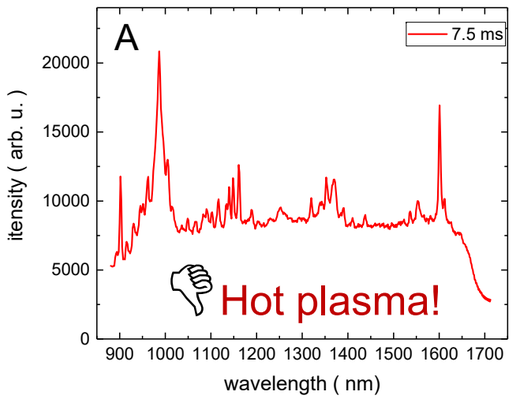
NIR optics for focusing

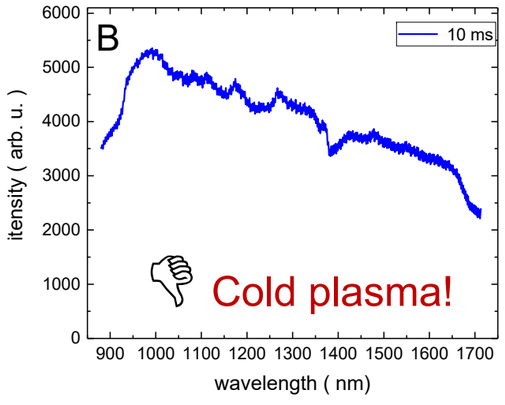
=

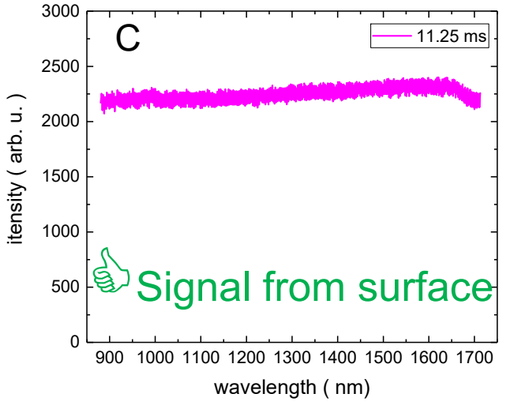


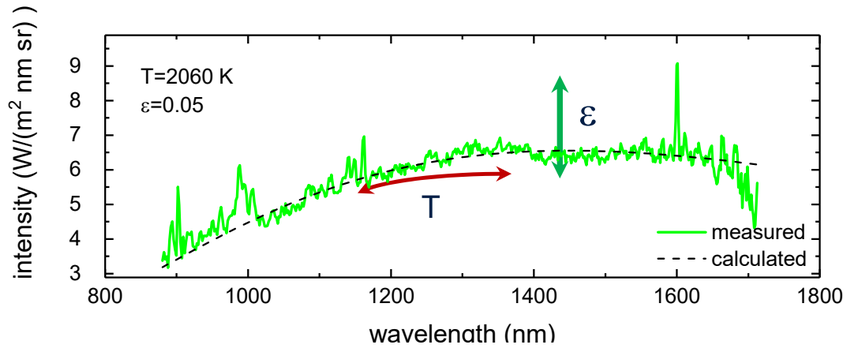


acquisition times









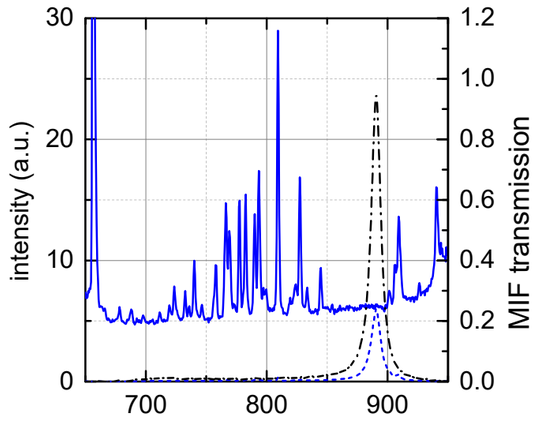
determination of T and ε from Planck fit

- Evaluation of NIR spectra emitted by hot electrode surface after current interruption
- Temporal resolution: 1 measurement each 1.25 ms

Methods: II high-speed camera (HSC) with filter

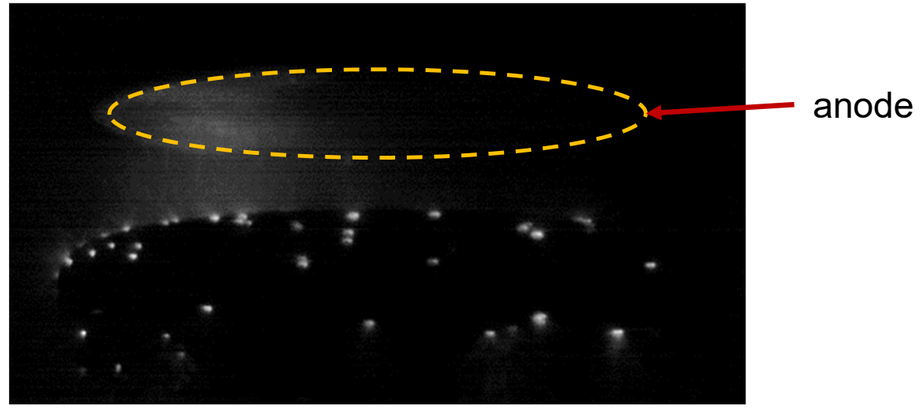
High-speed camera
IDT Motion Pro Y4
10000-20000 fps

+



filter, which “blocks” plasma radiation

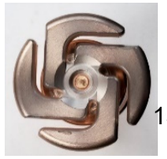
=

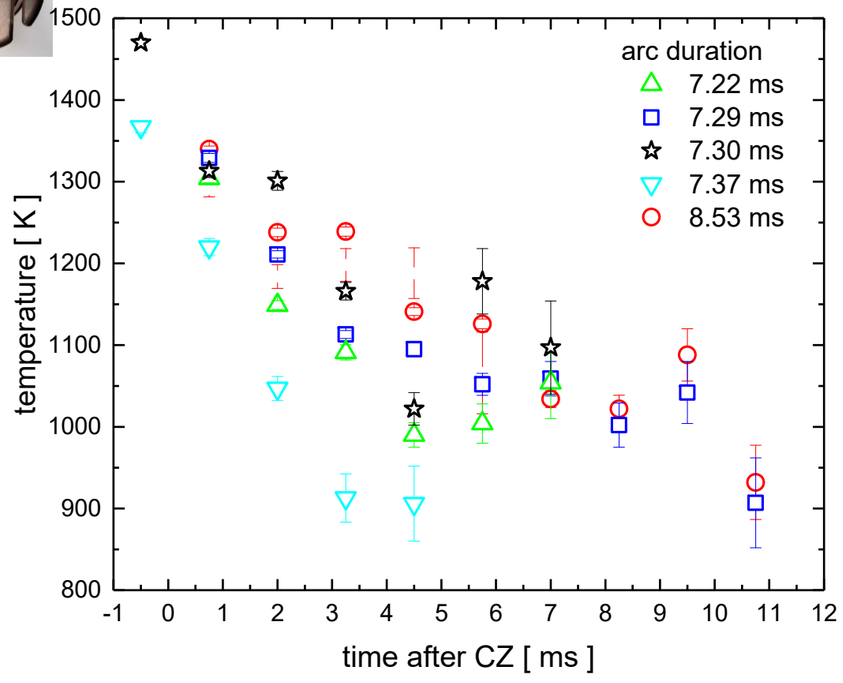


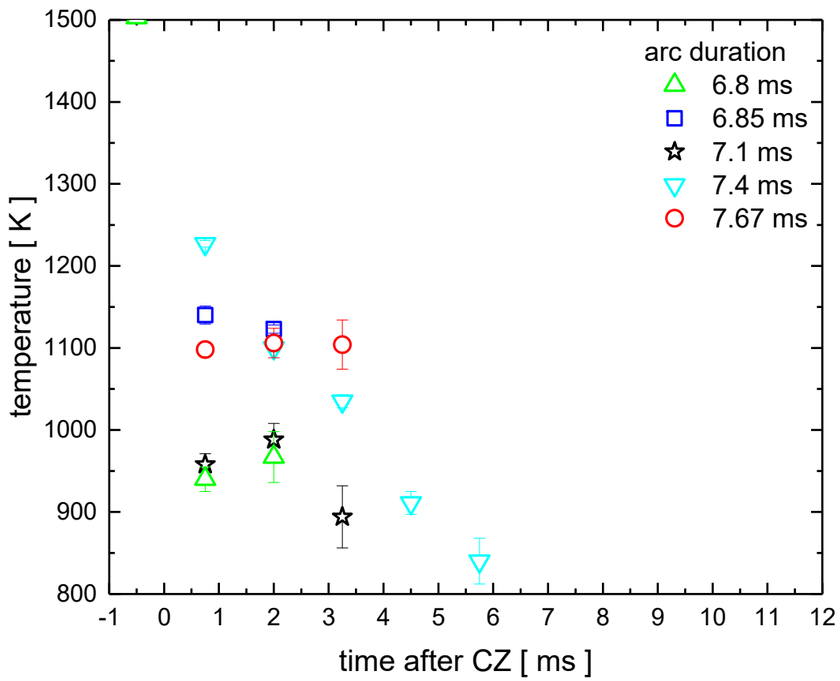
radiation image dominated by surface contribution

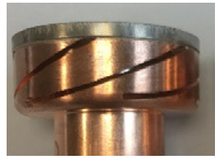
- The method gives **qualitative** 2D temperature distribution with high temporal resolution
- **Quantitative** temperature can be obtained after comparison with results of NIR measurements at certain spatial position and time instant
- Challenge: continuum radiation of plasma must be taken into account (“removed”)
- Subtraction of plasma radiation works well for diffuse arc only (AMF contacts) !

NIR results: anode surface temperature



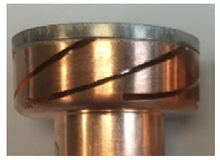


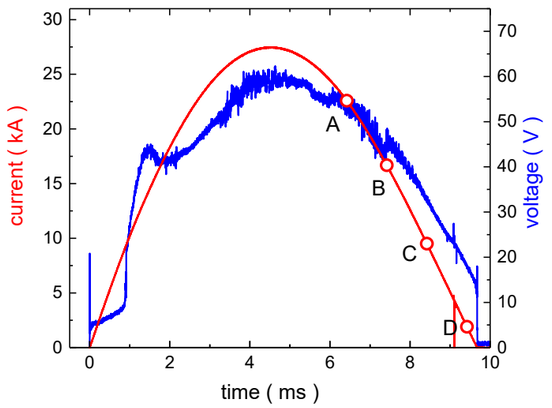


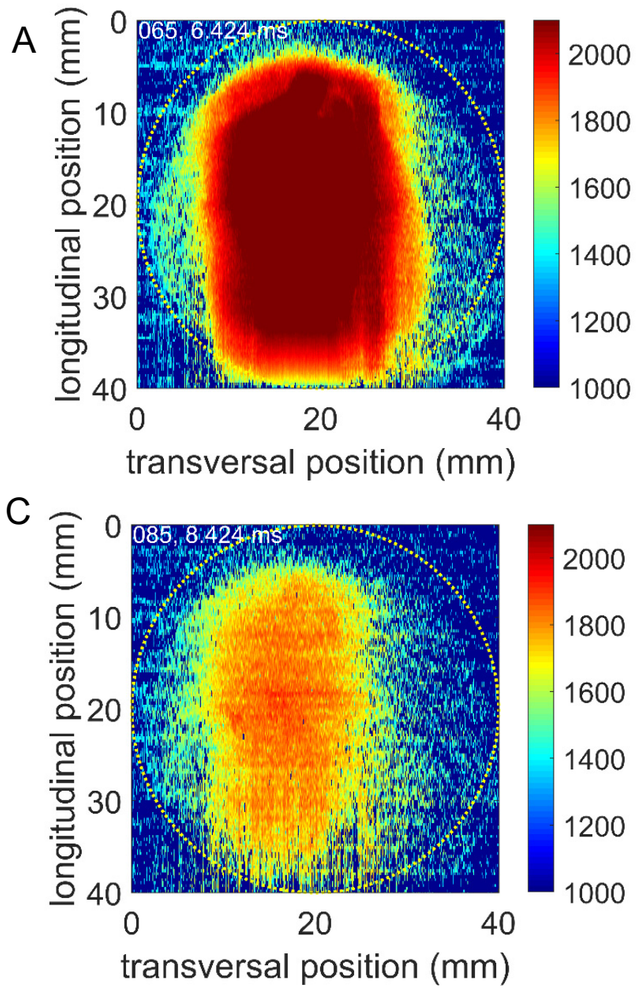


- Initial temperature in the range between 1200 K and 1420 K
- Higher temperature in case of constricted arc (TMF contacts)
- Tendency to higher temperature at longer arc duration in case of diffuse arc (AMF contacts)

HSC results: anode surface temperature







- Evaluation possible only after current maximum
- Melting point reached in a wide region

Summary

- Two optical methods for determination of surface temperature have been tested for switching vacuum contact systems.
- NIR spectroscopy works well for both type of contacts after current interruption (no plasma radiation).
- The method based on the high–speed camera techniques has restricted applicability. It works well for diffuse arcs and at certain electrode distance, which is typically reached after current maximum.
- RMF contact systems shows higher anode surface temperature after current interruption due to more localized thermal load comparing to AMF system.

Thank you very much for your attention!

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